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FOOD AND AGRICULTURE ORGANIZATION
REGIONAL OFFICE FOR ASIA AND THE FAR EAST
BANGKOK THAILAND

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THE INTERNATIONAL RICE COMMISSION

The International Rice Commission was established under the sponsorship of the FAO for the purpose of promoting national and international activity in respect of production, conservation, distribution and consumption of rice, except matters relating to international trade. At present it has 26 member governments, namely:

Australia	India	Pakistan
Burma	Indonesia	Paraguay
Cambodia	Iran	Philippines
Ceylon	Italy	Portugal
Cuba	Japan	Thailand
Dominican Republic	Korea	United Kingdom
Ecuador	Laos	United States of America
Egypt	Mexico	Vietnam.
France	Netherlands	

The First Session of the Commission was held in Bangkok, Thailand, March 1949; the Second Session in Rangoon, Burma, February 1950; the Third Session in Bandung, Indonesia, May 1952; the Fourth Session in Tokyo, Japan, October 1954; and the Fifth Session in Calcutta, India, November 1956.

For technical matters the Commission has special working groups. At first the Commission began with two working parties – one on rice breeding and the other on fertilizers – organized in 1950 and 1951 respectively. In 1954 the Commission added three more working groups to work on the topics of rice storage and processing; mechanization of rice production; and soil-water-plant relationships in the production of rice.

BREEDING FOR IMPROVED MILLING, PROCESSING AND COOKING CHARACTERISTICS OF RICE [1]

H.M. Beachell and John V. Halick [2]

THE improvement of the milling, processing and cooking quality of rice is an essential phase of rice production research in the United States of America. It is recognized that rice quality improvement is complex and difficult to accomplish and that specialized personnel and facilities are required. However, evidence will be presented showing that improved quality characteristics can be achieved through breeding.

In the United States three basic grain types of rice (long, medium and short grain) are grown and, for the most part, each grain type has been associated with specific processing and cooking characteristics. Preference is based primarily on cooking characteristics, flavor and appearance and, to a lesser extent, on grain size and shape. However, it would appear desirable to processors and consumers of rice if grain size and shape were continued to be associated with specific quality characteristics.

The quality characteristics associated with long-grain rice, when properly cooked, are that the cooked rice be dry and fluffy and the individual grains do not stick together or split. The individual grains of a properly cooked short-grain variety should be firmer than long-grain rice and the grains tend to stick together, and have a minimum amount of splitting. Medium-grain varieties should be intermediate in these respects.

In recent years new varieties of rice have been developed by inter-crossing short-, medium-, and long-grain varieties for the purpose of combining the desirable agronomic characteristics of the three grain-type groups into single varieties. The short- and medium-grain varieties used were *japonica* varieties and the long-grain varieties were sub-*indica* varieties originally obtained from the Philippines. High yielding varieties have been developed that are adapted to mechanized production methods. However, the desired quality characteristics have not always been achieved. Quality characteristics unlike either parent variety were found in Century Patna 231 and other selection resulting from *japonica*-sub-*indica* crosses. Century Patna 231 was selected from a cross between Texas Patna (sub-*indica*) and a hybrid selection from the cross Rexoro (sub-*indica*) x Supreme Blue Rose (*japonica*). The Century Patna variety produces lower "total" milled rice yields and the cooking characteristics are unlike any of the parent varieties. Milled rice of Century Patna 231 requires slightly longer to cook than Rexoro and the grains are more apt to split following cooking.

1 Contributed by the FCRB, ARS, U.S. Department of Agriculture and the Texas Agricultural Experiment Station for presentation at the 1956 Meeting of the International Rice Commission.

2 Research Agronomist and Chemist, FCRB, ARS, U.S. Department of Agriculture, respectively.

Most of the U.S. rice crop is milled to a relatively high degree. For this reason the processing and cooking characteristics that concern the consumer are the characteristics of the endosperm after the removal of the germ and bran layers. Varieties producing a minimum per cent of broken grains in the milling process as well as high percentage yields of "total" milled rice are required.

Evaluation of Processing and Cooking Characteristics

The quality evaluation of leading commercial varieties and breeding material was the first step in the quality breeding program. All known information on the quality behavior of commercial varieties was obtained. Samples of known purity were then given to industrial laboratories for evaluation.

The industry evaluation test that proved of most value for determining long-grain quality was parboiling followed by cooking under pressure in cans as carried out by manufacturers of canned soup. Samples of Century Patna 231, Bluebonnet 50, Texas Patna and Rexoro from date of seeding, date of harvest, and fertilizer rate and ratio experiments were tested by this method. These tests proved that the variability of milled rice is largely due to varietal differences. Environmental and other factors are no doubt responsible for certain differences in processing and cooking behavior and must be considered in the overall quality improvement program.

Industry tests are helpful in the final evaluation of a variety but these tests require large samples so other tests must be used in the early breeding generations. Techniques that require small samples and are based on sound chemical principles that depict known quality differences are being used to evaluate large numbers of hybrid selections in the early generations. Differences in chemical reaction are compared with known differences in processing or cooking behavior. A starchiodine-blue test and a cooking and soaking test have been perfected and described in detail by Halick and Keneaster (1). These tests have proved valuable because consistent results showing sharp varietal differences are obtained at a relatively rapid rate on small samples of rice.

In the starch-iodine-blue test one gram of ground rice is cooked in distilled water at 77° C. for 45 minutes. An iodine solution is then added to the clarified starch solution after cooking and the intensity of the blue color is measured with a photoelectric colorimeter. Typical results obtained with leading commercial rice varieties in the United States are shown in table 1. The intensity of the blue color produced indicates the relative amylose content of the rice. Varieties with low transmission values have an intense blue color, and consequently a high amylose content which is associated with good cooking and processing characteristics. For example, the lowest transmission values were obtained with the Nira, Texas Patna, Improved Bluebonnet, TP 49, and Rexoro varieties, which are superior in cooking and processing quality. Century

Patna 231 and other varieties which consistently show a high transmission value have not been suitable for processing purposes such as quick cook, parboiling, and pressure canning. Starch-iodine-blue values produced by short- and medium-grain varieties ranged from intermediate to high.

In the cooking-soaking test a small amount of cooked rice is placed in a petri dish, submerged in distilled water, and soaked overnight. Then the samples are examined critically for broken, split or odd-shaped grains. As shown in table 1, the results obtained by this method are in close agreement with the starch-iodine-blue test results. When properly cooked the short- and medium-grain types are characteristically firmer and more moist than the better long-grain types. Since the demand for these varieties is based on such characteristics, it is felt that the cooking-soaking test is not an accurate index of cooking quality for the short- and medium-grain types.

A large number of hybrid selections submitted by the breeders at cooperating state experiment stations have been evaluated for cooking quality using the two methods described above. Strains showing inferior quality characteristics can be eliminated in the early generations. However, other tests are needed as it is not anticipated that the present methods will adequately determine the processing and cooking characteristics of all rice varieties. This is particularly true in the case of the short- and medium-grain types.

In an attempt to develop new long-grain varieties possessing superior processing and cooking characteristics, 235 panicles selected at random from an F_2 population of a cross between Bluebonnet and Century Patna 231 were grown at Beaumont in 1953 by seeding each selection in a single nursery row 12 feet long and one foot apart. A total of 125 of the F_3 lines that appeared to have the most desirable agronomic and grain characteristics was harvested. A 200-gram sample of rough rice from each line was used for a parboiling and pressure canning test.[3] The quality determinations were based on the turbidity of the cook water and the firmness, degree of splitting, and checking of the cooked grain. A portion of the seed from each F_3 line was sown in individual rows in 1954 and those rated as possessing satisfactory processing and cooking characteristics were sown in F_5 generation bulk plots in 1955. Pedigree selections made from F_3 and F_4 rows also were grown each year.

Starch-iodine-blue values were obtained on the bulk populations that were grown in 1954 and 1955 and on 198 pedigree selections. Unfortunately, seed was not available for starch-iodine-blue determinations on the F_3 seed harvested in 1953. The parboiling and pressure canning tests were discontinued after the F_3 generation because of inconsistent results due to the limited amount of seed available.

Nineteen of the F_3 families were rated as having satisfactory quality characteristics

3 The rough rice samples referred to were parboiled and milled by the Comet Rice Mill, Houston, Texas, and the canning determinations were conducted by the Campbell Soup Company, Camden, New Jersey.

based on parboiling and canning tests. The samples rated as satisfactory showed relatively clear cook water, the grains remained firm, and there was a minimum of splitting of the cooked grains. The quantity of rough rice was not sufficient for duplicate tests so it was not possible to get reliable information on many of the samples. However, the parboiling and canning process was a rigid test and samples rated as satisfactory were considered to be of good quality.

Iodine values recorded on the unselected F_4 and F_5 populations of the 19 families classed in F_3 as being satisfactory for parboiling and pressure canning are shown in table 2. Iodine values recorded on F_4 and F_5 pedigree selections from these families are also shown in table 2. The iodine values for 15 of the 19 unselected F_4 and F_5 populations ranged from 22 to 32 per cent. The values for the remaining four families ranged from 40 to 65 per cent but only one reading exceeded 52 per cent.

The Century Patna 231 parent variety usually shows iodine values ranging from 70 to 80 per cent transmission and the Bluebonnet parent values from 25 to 32 per cent. In 1955 the Century Patna 231 bulk check plot sample gave a reading of 76 as compared with 32 per cent for Bluebonnet 50. Bluebonnet usually shows much the same iodine value as Bluebonnet 50.

Pedigree selections from 16 of the families were tested and low iodine value selections were recovered from 14 of these families. Selections with both intermediate and high iodine values were recovered from the other two families.

Some of the intermediate selections might be heterozygous for genes controlling this factor since progenies with low, intermediate and high iodine values have been found in selections showing intermediate reaction. Family A 3-100 is an example of this. Most selections with values of 30 per cent or below usually have low readings in later generations. Likewise, selections with values of 75 per cent or above usually have high readings in later generations. These observations are based on selections tested from the Bluebonnet x Century Patna 231 cross and several other crosses showing wide ranges in iodine values.

It will be noted in table 2 that selections with high iodine values were recovered from the bulk populations of families A2-1, A2-7, and A2-8. These three families had rather low iodine values in the F_4 and F_5 bulk populations. The selections with high iodine values in family A2-1 were progenies of an F_4 line that had on iodine value of 46 per cent. Only two F_5 selections with high iodine values were found in families A2-7 and A2-8 and they were both panicle selections from F_4 bulk populations. Their reaction in the F_4 generation is not known.

The generally close agreement between low iodine values and good cooking characteristics based on parboiling and pressure cooking tests indicates rather strongly that

the iodine test can be used effectively as an index of processing and cooking quality. The results reported from the Bluebonnet x Century Patna 231 cross show that lines with low or high iodine value can be recovered.

Evaluation of Milling Quality

In addition to cooking quality evaluation, rigid milling tests also are conducted to insure that any new variety released will produce high "head" (whole grain) and "total" milled rice yields. Most of the rice marketed in the United States is highly milled. A considerable number of the grains are broken during the milling process. It is recognized that environmental factors and storage conditions account for much of the variation in milling yields. However, there is considerable evidence to show that there are varietal differences in milling quality.

Samples of the rough rice that are to be milled are sealed in glass jars and kept at room temperature for a period of at least 24 hours to bring the moisture content to equilibrium before being milled. The moisture content is determined and a 125 gram sample is hulled in a McGill sheller and the weight of brown rice determined. In most cases a few unhulled grains were present in the brown rice sample. The weight of the hulls is determined by subtracting the weight of the brown rice from rough rice.

The brown rice sample is milled in a small McGill miller for 30 seconds using a weight of 14 pounds over a steel plate that covers the rice. The sample is immediately milled a second time for 30 seconds using a 4-pound weight. This second milling gives a high polish to the rice grains but causes very little additional breakage. The milled rice is sealed in a glass jar to prevent unnecessary breakage due to rapid or uneven cooling. The bran is screened through a 20 x 20 mesh wire screen to recover the small broken rice that passed through the miller screen. The finely broken rice thus recovered is aspirated and added to the milled rice. The term "total rice" represents milled rice after the hulls, bran, and germ have been removed and includes the broken grains. The milled rice is weighed when the rice has cooled to room temperature. The weight of the bran represents the weight of brown rice minus the weight of milled (total) rice.

The whole grains are separated from the total milled portion with a sizing device developed by the Grain Branch, Agricultural Marketing Service, United States Department of Agriculture. This device consists of indented plate, with flat-bottom holes, tilted at a slight angle and shaken by an eccentric mechanism. The rice travels the length of the sloping plate during the shaking motion and the broken grains fall into the indents in the plate. Plates with specific size indents are used for each grain type.

Whole grain rice (head rice) includes the whole grains and those grains with only a portion of the germ end (eye) broken off. After separation the whole grain and broken

grain portions are weighed. The percentage of hulls, brown rice, bran, whole grain, and broken grain is determined by multiplying the weight by the factor 0.8.

Average milling yields of leading commercial rice varieties in the United States are shown in table 3. The varieties were grown under uniform conditions and variations due to cultural or environmental factors were at a minimum. Texas Patna, TP 49, and Rexoro, late-maturing long-grain varieties, produced yields of whole grain (head) rice of 60.5, 53.3 and 58.9 per cent, respectively. Attention is also directed to the relatively high yields of total rice for Bluebonnet, Bluebonnet 50 and Sunbonnet, long-grain varieties of midseason maturity. Toro, a midseason maturing variety resembling Bluebonnet 50, has consistently produced high yields of whole grain rice. Century Patna 231, an early-maturing long-grain variety, has consistently produced low yields of total milled rice. It is concluded, therefore, that these are real varietal differences and that definite progress can be made in breeding for improved milling quality.

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Table 1 Quality Evaluation of United States Rice Varieties

Variety	FAO Genetic Stock Number	Parboiling-Canning Test	Cooking-Soaking Test	Iodine Per Cent Transmission
Nira (C.I. 2702)	215	VG	VG	16
Texas Patna (C.I. 8321)	221	G	VG	21
Improved Bluebonnet (C.I. 8992)	1016	G	VG	24
TP 49 (C.I. 8991)	1020	G	VG	25
Rexoro (C.I. 1779)	214	G	VG	26
Bluebonnet (C.I. 8322)	222	F	G	29
Bluebonnet 50 (C.I. 8990)	1012	F	G	31
Sunbonnet (C.I. 8989)	1019	F	G	32
Rexark (C.I. 8644)	210	VP	VP	59
Century Patna 231 (C.I. 8993)	1014	VP	VP	82

Explanation of symbols used:

VG = Very good
G = Good
F = Fair
P = Poor
VP = Very Poor

Table 2 Iodine Values of F_4 and F_5 Generation Bulked and Pedigree Line Selections from the Cross Bluebonnet x Century Patna 231 that were Rated Satisfactory for Processing Based on Parboiling and Canning Tests, 1954 to 1955, Beaumont, Texas

Unselected Bulk Pop.			Pedigree Selections			
	Iodine Value Per Cent		1954 (F_4)		1955 (F_5)	
F_2 Plant No.	1954 (F_4)	1955 (F_5)	No. Sels. Tested	Range of Iodine Value (%)	No. Sels. Tested	Range of Iodine Value (%)
A2 – 1	24	28	1	46	7	25 to 78
A2 – 7	25	24	2	25	15	18 to 80
A2 – 8	28	31	2	27 to 29	8	20 to 79
A2 – 66	26	26	3	24 to 30	4	20 to 22
A2 – 96	29	26	2	30 to 37	5	22 to 32
A2 – 98	23	22	3	19 to 35	8	22 to 31
A2 – 113	26	23	5	26 to 33	15	17 to 33
A2 – 119	23	28	5	21 to 25	5	20 to 24
A2 – 154	31	32	3	29 to 31	7	20 to 27
A3 – 51	26	30	NO SELECTIONS TESTED			
A3 – 52	27	26	0	–	5	27 to 38
A3 – 53	25	29	3	24 to 39	1	22
A3 – 69	31	31	0	–	7	26 to 38
A3 – 82	27	30	2	19 to 25	2	20 to 21
A3 – 89	49	49	NO SELECTIONS TESTED			
A3 – 97	42	51	0	–	2	43 to 89
A3 – 100	52	59	1	42	5	29 to 85
A3 – 103	31	30	NO SELECTIONS TESTED			
A3 – 106	47	65	1	50	4	49 to 76

Table 3 Average Milling Yields of United States Rice Varieties, 1953 – 1956 Beaumont, Texas

Variety	FAO Genetic Stock Number	Estimated Mill Yield (%)			
		Hulls	Bran	Whole	Total
Nira (C.I. 2702)	215	22.4	10.0	39.5	68.0
Texas Patna (C.I. 8321)	221	19.6	9.6	60.5	70.9
Improved Bluebonnet (C.I. 8992)	1016	20.9	11.1	49.5	68.1
TP 49 (C.I. 8991)	1020	19.7	8.9	53.3	71.4
Rexoro (C.I. 1779)	214	20.3	9.3	58.9	70.5
Bluebonnet (C.I. 8322)	222	20.2	9.5	42.0	70.3
Bluebonnet 50 (C.I. 8990)	1012	20.6	9.8	45.4	69.7
Sunbonnet (C.I. 8989)	1019	20.2	8.8	52.8	71.1
Rexark (C.I. 8644)	210	20.1	10.9	48.3	69.1
Century Patna 231 (C.I. 8993)	1014	23.6	11.1	52.7	65.5
Toro (C.I. 9013)		21.3	8.8	60.7	70.0
Magnolia (C.I. 8318)	216	20.9	9.2	58.5	69.9
Zenith (C.I. 7787)	206	21.0	9.4	58.1	69.6
Nato (C.I. 8998)		19.7	9.2	64.6	71.3
Caloro (C.I. 1561 - 1)	211	18.2	9.3	54.4	72.6

PRELIMINARY STUDIES ON ROOT PARASITIC NEMATODES OF RICE IN TEXAS AND LOUISIANA[1]

John G. Atkins, Max J. Fielding and John P. Hollis[2]

In 1954 *Radopholus oryzae* (v. Breda de Haan) Thorne was found for the first time in rice fields of Texas and Louisiana (1). The finding of *R. oryzae* stimulated a survey for other genera of root parasitic nematodes (2). Soil fumigation tests were initiated in 1955 to secure basic information and to evaluate the damage nematodes may cause on rice.

In 1954, 76 samples consisting of rice roots and surrounding soil were collected from widely separated rice fields in the States of Texas and Louisiana. A number of the samples were collected from recently harvested fields since such root samples seemed to yield the largest numbers of nematodes. In the laboratory the nematodes were separated from the soil and roots by the use of sieves and the Baermann funnel, and then examined to determine the presence of any possible species that were plant parasites. The plant parasitic nematodes found are listed in table 1. Large numbers of free-living (saprophytic or predacious) nematodes also were found.

Table 1 Parasitic or Suspected Parasitic Nematodes found in Rice Fields in Texas and Louisiana

Name of Nematode	*General Distribution* (Percentage)
A. Parasitic Forms	
1. **Radopholus oryzae** (v. Breda de Haan) Thorne	18
2. **Ditylenchus sp.**[1]	3
3. **Pratylenchus zeae** Graham, 1951	4
4. **Tylenchorhynchus martini** Fielding, 1956	66
5. **Tylenchorhynghus sp.**[1]	3
6. **Meloidogyne sp.**[2]	1
7. **Helicotylenchus sp.**[1]	5
8. **Hoplolaimus sp.**[1]	1
9. **Rotylenchus sp.**[1]	1
10. **Criconemoides sp.**[1]	3
11. **Paratylenchus sp.**[1]	1

1 *Contributed by the Field Crops and Horticultural Crops Research Branches, A.R.S., U.S. Department of Agriculture and the Louisiana and Texas Agricultural Experiment Stations for presentation at the 1956 I.R.C. Meeting.*

2 *Agent (Plant Pathologist) and formerly Assoc. Nematologist, A.R.S., U.S. Department of Agriculture and Assistant Plant Pathologist, Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana, respectively.*

Name of Nematode	*General Distribution* (Percentage)
B. Suspected Parasitic Forms	
1. **Psilenchus hilarulus** de Man	17
2. **Psilenchus aberrans** Thorne	3
3. **Psilenchus sp.**[1]	17
4. **Tylenchus sp.**	33
5. **Dorylaimellus virginianus** Cobb	9
6. **Dorylaimellus sp.**	8
7. **Longidorus sp.**	4

Of the parasitic nematodes listed in table 1, *Tylenchorynchus martini* was found most frequently, in 66 per cent of the samples. *Radopholus oryzae* was found in 18 per cent of the samples. Nematodes of the genera *Ditylenchus, Pratylenchus, Paratylenchus* and *Rotylenchus* were found in only a limited number of fields, but their populations frequently were high. Although nematodes belonging in the genus *Ditylenchus* were found in the soil-root samples, such nematodes may not have been root parasites. Some of the nematodes found and included in table 1 may be primarily parasites not of rice but of other plants. Proof of parasitism has been established only for *Radopholus oryzae* and *Tylenchorhynchus martini*.

The nematode populations were found to vary greatly from one rice field to another. Larger numbers of parasitic nematodes were found mostly in fields that had grown 2 or more consecutive crops of rice. The practice of growing only 1 or 2 consecutive rice crops in a rice-pasture rotation probably influences nematode populations.

In 1955 four soil fumigation tests were conducted with the 4 commercial nematocides listed in table 2. The purpose of these tests was to measure the damage to rice by nematodes and the benefits from their control. The nematocides were used 2 to 3 times the regularly recommended rate of application for other crops to obtain a high degree of nematode control. The treatments used cost from $ 80 to $ 800 per acre. Inconclusive results were obtained from two tests in Louisiana (4).

One of the 1955 tests on a commercial rice farm in Chambers County, Texas, gave some interesting results (table 2) (3). The predominant parasitic nematode in the test area prior to treatment was *T. martini*, but smaller numbers of other parasitic nematodes, such as *Pasilenchus sp.* were encountered. The chemicals were applied in April in 14 x 20-foot replicated and randomized plots with 4-foot alleys, following thorough soil preparation of the experimental area. The MC-2 was applied under polyethylene covers which were removed after 48 hours. The other treatments, Dowfume W-85, D-D Mixture and Nemagon, were applied with a MacLean Fumigun at a 6-inch depth and at 12-inch intervals. The plots were sown with Bluebonnet 50, a representative Texas rice variety approximately one month fol-

1 Undescribed species
2 Only males and larvae found

lowing treatment. Fertilizer was purposely omitted from the plots since it was assumed that injury from nematodes would be more pronounced at lower fertility levels. Samples from the plots were harvested at maturity. The yields are given in table 2.

Table 2 Results for Soil Fumigation Experiment, Chambers County, Texas, 1955.

			Yield, per acre		
				Increase over control	
Treatment	*Active Ingredients*	*Dosage*	*Pounds*[1]	*Pounds*	*Per Cent*
Dow fume MC-2	Methyl bromide 98%	3 lbs./100sq. ft.	2656.8	826.2	45.1
Dow fume W-85	Ethylene dibromide 83%	12 gallons/A	2462.4	631.8	34.5
D-D Mixture	Dichloropropane-Dichloro-propane Mixture 100%	40 gallons/A	2349.0	518.4	28.3
Nemagon	1, 2-Dibromo-3, Chloropropane	5 gallons/A	2365.2	534.6	29.2
Control	–	–	1839.6	–	–

L.S.D. .05 = 414.6 lbs. per acre
L.S.D. .01 = 603.3 lbs. per acre

The plots treated with nematocides gave consistent and statistically significant higher grain yields than the untreated control plots. The rice plants on treated plots were noticeably taller and darker green in color. The plots treated with MC-2 were conspicuously better in appearance than the others. Satisfactory nematode control was obtained with each of the nematocides, as determined by soil and root samples taken from the plots at three stages of plant growth.

Methyl bromide and ethylene dibromide were used in a test at the Rice Pasture Experiment Station, Beaumont, Texas, where the predominant parasitic nematodes were *Radopholus oryzae* and *Tylenchorhynchus martini*. The test was conducted in 1955 in a manner similar to the one above. In this test the population of *R.* oryzae was high at the end of the season in plots treated with Dowfume W-85 as indicated in table 3. Average yields are included in table 3.

Table 3 Results for a Soil Nematocide Test at Beaumont, Texas, 1955.

	Av. Nematode Counts[2,4]		*Height*[4]	*Grain Yield*
			(Tip of Panicle)	*per acre*
Treatment and Dosage	*T.M.*[3]	*R.O.*[3]	*Inches*	*Pounds*[4]
MC-2, 2 lbs./100 sq. ft.	0	0	46.2	2097.1
Dowfume W-85, 12 gallons/A	2	178	44.2	1679.7
Control	387	229	42.5	1552.6

1 *Average of 3 replications of dry cleaned rough rice.*
2 *Average number nematodes per pint sample consisting of soil and rice roots at maturity of plants.*
3 *T.M.* = **Tylenchorhynchus martini.** *R.O.* = **Radopholus oryzae.**
4 *Averages of 4 replications.*

The MC-2 (methyl bromide) gave excellent nematodes kill and higher rice yields than the controls as well as taller plants that had darker green leaves. The effect of Dowfume W-85 (ethylene dibromide) was not so pronounced as that of the MC-2 treatment. The populations of *R. oryzae* were nearly as high in Dowfume W-85 plots at maturity of the rice as in the untreated plots.

Studies are being continued on the root parasitic nematodes of rice in Arkansas, Louisiana and Texas. The results of the 1956 tests were not available for inclusion in this paper.

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TESTING AND BREEDING AMERICAN RICE VARIETIES FOR RESISTANCE TO STRAIGHTHEAD[1]

J.G. Atkins, H.M. Beachell and L.E. Crane[2]

Straighthead, a physiological or nonparasitic disease, is one of the more important disorders of rice in the southern rice area of the United States. The disease has been known for many years (4). Straighthead apparently is caused by certain soil conditions resulting from prolonged flooding. However, straighthead occasionally has occurred on lands where arsenic accumulated from applications of arsenical insecticides to the cotton over many years.

Straighthead has been controlled or alleviated in susceptible rice varieties by timely draining and drying of the soil. Indications are that fields should be drained just prior to the initiation of the reproductive stage of growth (3). However, the growing of resistant varieties is more economical than the practice of draining.

The symptoms of straighthead are quite distinct. Panicles on affected plants remain upright at maturity because the few grains formed are too light to bend the panicle over in a normal manner. The sterility of characteristically diseased panicles frequently is complete. Typically the hulls are distorted into a crescent or "parrot beak" form, and either the palea or lemma, or both, may be lacking. The pistil and stamens of affected flowers are also generally absent. Distorted hulls are very prevalent in the long-grain varieties. In severe cases the panicles are greatly reduced in size and emerge slowly or incompletely from the boot. Affected plants remain vegetative with a dark green color and frequently produce tillers from the lower nodes.

Affected plants of varieties, such as Colusa (C.I. 1600), in the shortgrain group frequently show excessive sterility with little or moderate glume distortion. Such varieties must be considered as susceptible to straighthead since they produce little grain. Initially the writers erroneously regarded glume distortion as the primary symptom or criterion for straighthead and considered Caloro and Calrose as resistant varieties(1, 2).

Although straighthead has attracted the attention of a number of research workers, the sporadic occurrence of the disease resulted in limited progress as the disease could not be induced for testing purposes. However, it fortunately was discovered that continuous flooding from the time of initial irrigation until the rice is mature consistently

1 *Contributed by the Field Crops Research Branch, ARS, U.S. Dept. of Agr. and Texas Agricultural Experiment Station for presentation at the 1956 IRC Meetings.*

2 *Agent (Plant Pathologist), and Research Agronomist, Field Crops Research Br., Agricultural Research Service, U.S. Department of Agri.; and Supt., Rice Pasture Experiment Station, Beaumont, Texas, respectively.*

induced straighthead in susceptible rice varieties when grown on Hockley fine sandy loam, one of the soil types comprising the Texas rice area (5).

Many U.S. rice varieties and breeding lines were tested in special nurseries, in 1954, 1955 and 1956, in order to determine their reaction to straighthead. Each entry was sown in single or duplicated 12-foot rows, spaced 12 inches apart. Thin seeding permitted the observation of individual plants. The test area was flooded approximately 30 days after the plants emerged and was kept flooded until maturity. Variation in disease severity occurs over the test area so a susceptible variety, Century Patna 231, was sown in every twentieth row as a check. In most cases a susceptible reaction in one year is accepted as conclusive but resistant or moderately resistant strains are tested two or more years.

Table 1 shows the origin, and reaction to straighthead, of 28 U.S. rice varieties and, in many cases, the reaction of their parental variety. Although considerable information as to varietal reaction has been published from general observations over many years, the accompanying ratings were recorded under uniform test conditions. Unfortunately, many of the popular varieties listed in table 1 are susceptible to straighthead. The data indicate that Fortuna (CI 1344) and CI 5094 are the primary sources of resistance in the long-grain group. The resistance of Prelude, Bluebonnet, Bluebonnet 50 and Toro apparently was derived from Fortuna and the resistance of Texas Patna from CI 5094. Fortuna was selected in 1911 from the Pa Chiam variety obtained from Formosa and CI 5094 was selected from the Sinanpagh variety from the Philippines in 1916.

The development of straighthead resistant rice varieties became a definite objective of the rice breeding program in 1954. Techniques for evaluating rices for resistance were not then available but were soon developed. The reaction of leading rice varieties, selections and foreign introductions was determined. Advanced generation selections from crosses involving Fortuna, CI 5094 or their derivatives were then tested. Wherever possible a number of panicle rows of such strains have been grown. Hybrid populations have been examined in the F_3 and F_4 generation panicle rows.

More than 3000 rice varieties and selections from the rice experiment stations of Texas, Louisiana, and Arkansas have been evaluated for straighthead reaction during the past three years. Selections from crosses between two straighthead susceptible varieties, such as Blue Rose, Zenith, Rexoro, or Nira, have been susceptible with one or two possible exceptions. The progenies of crosses between a resistant and a susceptible variety, such as Bluebonnet x Century Patna 231, have segregated for resistant and susceptible plants or lines. The number of genes involved in straighthead reaction has not yet been established but it appears to be

relatively simple in crosses within the long-grain group of varieties. Resistance seems to be dominant. Straighthead resistance has not been found to be linked or associated with any morphological character.

Many very promising straighthead resistant strains now are available for general field testing and quality evaluation. The incorporation of straighthead resistance in all new varieties developed should be an important contribution to domestic rice production.

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Table 1 Reaction of United States Rice Varieties and their Parents to Straighthead

Variety and Reaction Group	*C.I. No.*	*FAO Genetic Stock No.*	*Parentage or Origin*	*Parental Reaction*	*Variety Reaction*
Resistant					
Bluebonnet	8322	222	Rexoro x Fortuna	SxMR	MR
Bluebonnet 50	8990	1012	Selection from Bluebonnet	SxMR	MR
Century Patna	9372	–	Texas Patna x (Rexoro x Supreme Blue Rose)	Rx (VSxS)	R
Fortuna	1344	220	Selection from introduction	–	MR
Lacrosse	8985	1017	(Colusa x Blue Rose) x (Shoemed-Fortuna)	(SxS x (? x MR)	MR
Prelude	8311	209	Improved Blue Rose x Fortuna	SxMR	MR
Texas Patna	8321	211	Rexoro x CI 5094	VSxR	R
Toro	9013	– [1]	Bluebonnet x (Rexoro x Blue Rose-Rexoro)	MRx (VSxS-VS)	MR
Susceptible					
Arkrose	8310	207	Caloro x Blue Rose	MSxS	MS
Blue Rose	2128	217	Selection from unknown variety	–	S
Caloro	1561-1	211	Selection from introduction	–	MS
Calrose	8988	1013	(Caloro x Calady) x Caloro	(MSx?) xMS	MS
Century Patna 231	8993	1014	Texas Patna x (Rexoro x Supreme Blue Rose)	Rx (VSxS)	S
Century 52	9002	–	Texas Patna x (Rexoro x Supreme Blue Rose)	Rx (VSxS)	S
Cody	8642	212	Colusa x Lady Wright	SxS	MS
Colusa	1600	213	Selection from introduction	–	S
Early Prolific	5883	219	Selection from unknown variety	–	S
Improved Bluebonnet	8992	1016	Rexoro x Nira	VSxS	S
Kamrose	8314	208	Kameji x Blue Rose	?xS	MS
Magnolia	8318	216	Improved Blue Rose x Fortuna	SxMR	S
Nato	8998	– [1]	(Rexoro x Purple Leaf) x Magnolia	(VSx?) xS	MS
Nira	2702	215	Selection from introduction	–	S
Rexark	8644	210	Rexoro x Supreme Blue Rose	VSxS	S
Rexoro	1779	214	Selection from introduction	–	VS
R–D	8643	1018	Rexoro x Delitus	VSxS	S
Sunbonnet	8989	1019	Selection from Bluebonnet	MR	VS
TP 49	8991	1020	Texas Patna x (Rexoro x CI 7689)	Rx (Sx?)	VS
Zenith	7787	206	Selection from Blue Rose	(S)	S

Explanation of symbols used: R = Resistant
MR = Moderately Resistant
MS = Moderately Susceptible
S = Susceptible
VS = Very Susceptible
? = Variety Not Tested.

1 *This variety will be listed in supplement No. 6, World Catalogue of Genetic Stocks, F.A.O.*

REPORT ON THE PROCESSING AND STORAGE OF RICE IN MALAYA

A.E. Billington, Senior Chemist

Department of Agriculture
Federation of Malaya

INTRODUCTION

The report which follows is a summary of present knowledge of conditions in Malaya on the processing and storage of rice and their related problems.

In 1955, rice imported into and produced in the Federation of Malaya totalled approximately 894,900 long tons. Of this 410,600 tons was locally produced (1), and 484,300 tons imported ((2) and (3)). Some of the local paddy, milled by the growers for home consumption, was under-milled to varying degrees, but the great bulk of both imported and local rice was consumed as highly milled white rice. Parboiled rice amounts to only 3 per cent of the total consumed.

PROCESSING OF RICE

Approximately half the local rice is milled in large mills for commercial sale as white rice. Milling for home consumption by the cultivators is either done by traditional means (household mills), or by small power-driven mills. Simpson (4) has given a full account of these three types of milling, of which the following is a summary:

Large mills These are situated near the main producing areas (the States of Kedah Perlis, Kelantan, Perak and Selangor). The capacity of these mills is between 7-27 tons of rice per 8-hour day. Thomson (5) has estimated that overall milling capacity is more than adequate for present or near-future needs. The capacity for 8 months production at 10-hour working day is 350,000 tons of rice annually (5). There are some 50 self-contained automatic mills, of which 5 are Government owned, and one large mill is a Co-operative venture.

The efficiency of these mills varies widely, due to paddy types and conditions, maintenance of machines, etc. The following yields from a good mill have been quoted by Simpson (4):

Type of Product	*Yield from paddy*
White, highly milled rice	65 – 70 %
Broken rice	3.3 – 6.1 %
Bran No. 1	2.2 – 4.6 %
Bran No. 2	4.8 – 5.0 %
Husk, Dirt, etc.	20 %

Small mills It has been estimated (5) that there are over 400 small mills scattered over the country, about half of them being in Kedah. Capacity of the mills is 1–2 pikuls per hour (1–2 ¼ cwt. hr.). The machines remove the husk and bran in one operation, giving milled rice and a coarse bran mixed with ground husk. The latter is inferior to Bran No. 2 produced by the large mills. The machine is of the type known as "Tamping machines" (6), consisting of a heavy fluted rotor, rotating on a horizontal axis within a stationary slotted cylinder, the slots being 3" long by 0.06" wide. The flutes of the rotor are so made that the paddy is carried along the cylinder while being rolled around the inside of it. The action is essentially one of scouring, the husks falling through the slotted outer cylinder. Husks remaining with the milled rice are separated by blowing, which may be incorporated in the machine itself. The efficiency of these machines is very variable, bad operation or deliberate mishandling of the adjustments produce excessive rice breakage. Results given by Simpson (4) show that samples with as much as 72 per cent broken grains have been encountered.

Simpson (4) has also reported that a better type of small mill is now appearing in Malaya, in which a disc-huller is provided and followed by a polisher, one pass in the latter producing under milled rice and two passes giving a highly milled product.

Household mills These primitive appliances have been described by Jack (7) and Simpson (4). They are all based on the principle of the pestle and mortar, the contact surfaces being made of wood. The product of the pounding is separated by hand-winnowing. The examination of 158 samples of 'village' rice has been reported by Simpson (8), results showing 15 per cent of the samples only husked or under-milled, 51 per cent under-milled and 34 per cent highly milled.

Pre-cleaning and grading machines Only the large mills use pre-cleaning machines. Grading of paddy or rice is not practised at all.

Research and milling Simpson (4) has reported that no research on milling methods had been undertaken in Malaya. Tests have been carried out with improved designs of machines produced overseas, but no practical progress has been reported. A joint meeting of government experts convened by the Director of Medical Service, Malaya, late in 1954, recommended that a Rice Process Research Unit be set up as soon as possible, probably within the Department of Agriculture.

RICE STORAGE

Threshing and storage quality Threshing of the local crop is carried out by primitive hand methods, as described by Jack (7). The ears of rice are either laid on matting and pounded by treading to release the grain, or the ears are beaten on the inside of a wooden tub in the harvest field to loosen the grain. The paddy is hand winnowed and spread on matting to dry. Simple hand-operated winnowing machines are also used.

Investigations carried out by the Department of Agriculture on harvesting and threshing of paddy by mechanical methods have been reported by Allen and Haynes (9) and Haynes (10). So far these methods are not in general use, and no attempt has been made to correlate harvest and threshing conditions with storage quality.

Village storage Paddy for local consumption or for later sale to mills is always stored in bulk. The main type of store is the "jelapang" of Kedah, which has been described by Sands (11). Thomson (5) reported few signs of infestation in these stores, but pointed out that they could be improved by rat-proofing. A variety of construction materials are used, but the structure is essentially a wooden frame building with raised wooden floor. The walls are of planks or woven split bamboo. The door is fitted with vertical slides so that planks can be inserted to close the doorway as the paddy level rises. The building is roofed with "attap' (palm leaves) or corrugated metal sheeting. The usual capacity of the store is 4,000 to 5,000 gantangs (gallons) (10-12 tons).

Storage at mills Both paddy and rice are stored in jute bags at mills. Thomson (5) has recorded that mill storage facilities in Malaya are generally superior to those in Burma, Thailand and Indo-China. Most losses can be attributed to lack of cleanliness in maintaining the stores, but even this is minimised by the fairly rapid turnover in locally grown rice, which is the normal practice.

Government stores Bulk-purchased rice is handled and distributed through government godowns. Although these were run satisfactorily in the immediate post-war period, new structures are now in use and some of the old stores have been abandoned.

Oxley (12) commented favourably on these storage facilities, and the steady improvement being made. The new Federation of Malaya godowns on Singapore Island is reported to be potentially one of the finest godowns in the world for bagged grain (12).

Good standard procedures are maintained in these godowns, e.g., use of sound dunnage, BHC dust to minimise insect damage, rat control measures and control of bird entry. Oxley (12) reported that bird damage is probably the main cause of losses in these godowns.

Research on storage Early experiments on rice storage were reported by Jack & Jagoe (13) who showed that, under good storage conditions, rice could be stored up to two years, compared with 4-6 months maximum of commercial practice. Recommendations for good storage practice were made by Jagoe (14). Experiments were also conducted on the storage of undermilled rice (Jagoe (15)), in which it was shown that, under good storage conditions, such rice could be stored in good edible condition for up to five months.

As a result of the recommendation made by Oxley (12), a program of research into rice and other storage was initiated as a

joint effort of the Supplies Department, the Institute of Medical Research, the Public Works and the Agriculture Departments. Work has fallen into two categories:

(1) Storage experiments in godowns to estimate losses, and trials for their elimination.

(2) Bulk storage experiments in experimental silos.

Results of the first series of experiment on bag storage show that real losses of stored rice should not exceed one per cent, when good storage practices are followed (16).

The first experiment on bulk storage of rice was only partly successful. Modifications are now being made to the silo in preparation for further trials.

Artificial drying This is not normally practised in Malaya. Paddy is harvested in the dry season and is sun-dried before storage and milling. Lack of control at this stage may increase breakage in milling due to "sun-cracking".

PARBOILING AND RICE ENRICHMENT

The study of the nutritional value of rice and its improvement has been carried out for many years at the Institute of Medical Rerearch, Kuala Lumpur. This work has been fully reported by Simpson et al. (4), (17). The only reliable source of parboiled local rice in Malaya is the Government Rice Mill at Anak Bukit, Kedah, where Simpson's recent experiments have been carried out.

Parboiling went out of use during the period of Japanese occupation and its use is only making a slow recovery in the post-war period.

Recent acceptance trials by Simpson (4) showed high acceptance of well prepared parboiled rice (lowest 50 per cent and highest 90 per cent of tasters, according to race).

The method used for preparing the parboiled rice was as follows: (4)

(1) Soaking – 24 hours, fresh water every 6 hours.

(2) Steaming – drained paddy steamed at 40 lbs/sq. in. for 10 mins.

(3) Drying – sun dried to moisture less than 15 per cent.

(4) Milling – normal for highly milled rice, after a few days of storage.

While this process is not new, the trial has shown that wide consumer acceptance is likely for well-prepared parboiled rice. The obstacle to further progress in Malaya is the lack of artificial drying facilities suitable for the wet paddy produced in this process.

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FERTILIZER EXPERIMENTS ON PADDY IN EGYPT

M.A. Koshairy[1], C.L. Pan[2], Gad El Hak[3]
I. Sirry, Abo Zaid, A. Azizi, C. Hindi and M. Masoud[4]

The experimental results presented in this report can be divided into two parts, namely: the interaction between varieties and fertilizer and the methods of applying fertilizer in relation to paddy yield and to protein content of the rice grain.

INTERACTION BETWEEN VARIETIES AND FERTILIZER

In 1955, a trial was conducted in Gemmeiza, consisting of 240 entries. Each was transplanted to a plot of 3.6 metres long and 20 centimetres apart with 3 replications. In each replicate the varieties were systematically arranged with every 10th row planted to Yabani Mont. 47, our standard variety, as a check plot. This trial was repeated in three adjacent fields, each receiving a different amount of nitrogen, namely: 47.62 kgs., 95.24 kgs. and 142.86 kgs, per hectare in the form of ammonium sulphate.

The yields of Yabani Mont. 47, obtained in the three fields were analysed. As there were 240 entries in this trial, and every 10th plot was planted to this check variety, there were altogether 24 plots, of which the yields were averaged and the standard error of the mean was calculated. The results are presented as under:

Table 1 Average Yield of Yabani Mont. 47 in the Three Fields Each Receiving a Different Amount of Nitrogen

Treatment Number	*Amount of nitrogen* (kgs.) *added per hectare*	*Average yield in kgs. per hectare*	*Difference in kgs. per hectare*
1	47.62	7,800.15±102.29	
2	95.24	6,648.70+139.07	1,151.45±172.29
3	124.86	7,191.57+512.63	608.58±522.74
			542.87+531.16

Treatment No. 2 yielded 1,151.45 kgs. less than treatment No. 1 and 542.87 kgs. less than treatment No. 3, whereas treatment No. 1 yielded 608.58 kgs. more than treatment No. 3, but only the difference between treatment 1 and treatment 2 was significant.

1 Director of the Plant Breeding Section
2 FAO Rice Production Expert
3 Chief of the Rice Branch of the Plant Breeding Section
4 Rice Breeders of the Rice Branch of the Plant Breeding Section, Ministry of Agriculture, Cairo, Egypt

The results at least had proved that to use more than 47.62 kgs. of nitrogen per hectare would not increase the paddy yield of Yabani Mont. 47.

This conclusion seemed to agree with the general practice followed by the rice growers in this country that usually not more than 100 kgs. of ammonium sulphate were used in each *feddan*, which is equivalent to 47.62 kgs. of nitrogen per hectare. Numerous fertilizer trials have been conducted during the past 10 years, and all the results obtained also showed that this was the optimum rate. All of our breeding trials in which Yabani Mont. 47 was included were conducted in nurseries using this amount of nitrogen. This may help to explain that Yabani Mont. 47 gave the best response at this rate of manuring.

This trial was aimed at isolating some varieties that might display a better response when more fertilizer was used. The yield of each of the 240 entries grown in each of the three fields was compared with that of Yabani Mont. 47, and those yielding significantly higher were selected and their response to the different rates of fertilizer was studied.

A total of 53 such varieties was found to be very promising and according to their mode of response, they can be classified into 3 groups as under:

Table 2 Varietal Response to the Various Rates of Manuring

Group	*No. of varieties*	*Average yield at the various rates of manuring (kgs./hectare)*		
		at 47.62 kgs.	*at 95.24 kgs.*	*at 124.86 kgs.*
I	8	6,743.00 (100%)	8,685.89 (128.8%)	10,543.07 (156.4 %)
II	37	7,828.73 (100%)	10,771.64 (137.59%)	8,343.02 (106.57%)
III	8	8,543.03 (100%)	6,628.70 (77.59%)	11,028.79 (129.10%)
Average yield of Yabani Mont. 47		7,800.15	6,648.70	7,191.57

The first group of 8 varieties gave a linear response, i.e. the yield increased as the fertilizer increased. Its average yield in the fields receiving double dressing and treble dressing was found to be much higher than that of Yabani Mont. 47 when only single dressing was used.

The second group of 37 varieties, however, displayed a curvilinear response. The yield increased when the fertilizer was increased from single dressing to double dressing but decreased when the fertilizer was further increased from double dressing to treble dressing. Their yield with double dressing was much higher than that of Yabani Mont. 47 with single dressing.

The response of the third group was rather unusual. The yield was first depressed when the fertilizer was increased from single dressing to double dressing but

when the fertilizer was further increased from double dressing to treble dressing, the yield was greatly increased.

In 1956, these 53 varieties highly responding to fertilizer were further tested in two places with 5 rates of manuring, namely: nil, 47.62 kgs. of nitrogen per hectare, 95.25 kgs. per hectare, 142.86 kgs. per hectare, and 190.48 kgs. per hectare; and in each treatment, except for the nil plot, 50 kgs. of P_2O_5 in the form of superphosphate being added. Results from this trial are not available.

METHODS OF APPLYING AMMONIUM SULPHATE

When ammonium sulphate is broadcast on the surface of a waterlogged paddy field, the ammonium (NH_4+) are easily oxidized to nitrate ions (NO_3+). The nitrate ions are easily leached to deeper layers of the soil where they are reduced to nitrogen and thus lost to the paddy crops. But if ammonium sulphate is applied in the sub-surface soil, most of the ammonium ions would remain unionized and could be directly absorbed by the rice roots.

Two trials were conducted in 1955, using 47.62 kilograms of nitrogen per hectare in the form of ammoninm sulphate and 50 kgs. of P_2O_5 in the form of superphosphate. These fertilizers were applied in two different ways, one deep placement and the other surface placement. The results obtained are presented as follows :

Table 3 Paddy Yields of the Different Treatments (kgs. per hectare)

Method of application	*Ammonium sulphate*	*Superphosphate*
Deep placement	7,657.3	7,514.4
Surface placement	7,228.7	7,371.6

The deep placement of ammonium sulphate yielded significantly higher than the surface placement, while the difference between deep and surface placements of superphosphate was not so significant.

In 1954, a similar trial was conducted only with ammonium sulphate. The data from this trial and those from the 1955 trial were put together in one table as follows :

Table 4 Average Yield of the Two Methods of Applying Ammonium Sulphate in 1954 and 1955

Method of application	*1954*	*1955*	*Average*
	kgs. per hectare		
Deep placement	6,828.7	7,657.3	7,243.0
Surface placement	6,285.8	7,228.7	6,757.2

The average yield of deep placement, was 7,243.0 kgs. per hactare, as compared with only 6,757.2 kgs. for surface placement their difference being statistically significant.

The protein content of the rice grains harvested from the trial conducted in 1955 was analysed by the Grain Laboratory of the Chemistry Section. Each sample was analysed twice, and the percentage of protein was obtained by multiplying the total nitrogen by 6.25.

Table 5 The Average Protein Content of the 4 Treatments

Method of placement	*Ammonium sulphate, percent*	*Super-phosphate, percent*
Deep placement	6.1	5.9
Surface placement	5.4	5.6

The standard error of the above means was found to be 0.02 percent and the least significant difference between any two treatments at the 5 percent point was 0.08 percent.

The protein content of the grains in the plots with deep placement of ammonium sulphate was 6.1 percent as compared with only 5.4 percent for the surface placement plot, their difference being highly significant. Similar results were obtained from the superphosphate treatment, but their difference was much smaller than that of the ammonium sulphate treatment.

SUMMARY

1. Varietal difference in response to fertilizer was observed. Yabani Mont. 47 gave its best yield when 47 kgs. of nitrogen per hectare was used. But many varieties were found to yield higher than Yabani Mont. 47 if more fertilizer was used.

2. The yield of paddy increased when the ammonium sulphate was applied into the sub-surface soil instead of on the surface soil. This deep placement would also increase the protein content of the grains.

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